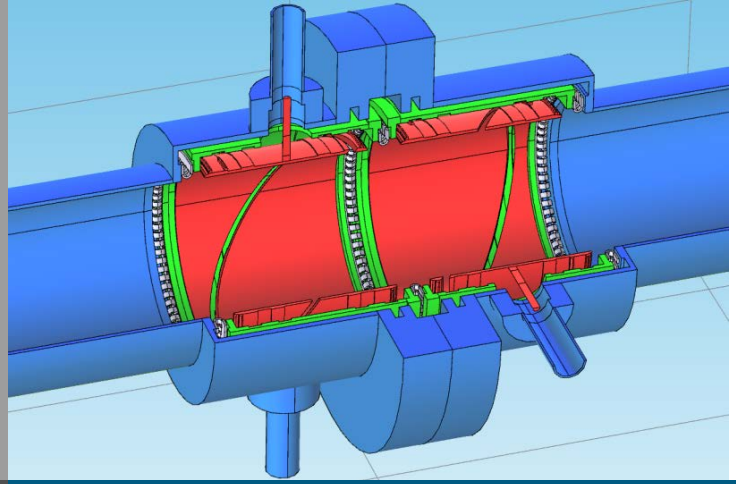
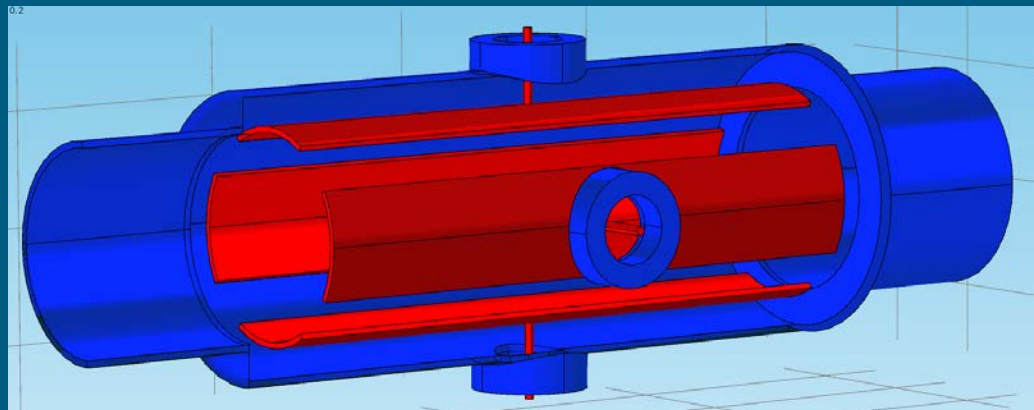


JÜLICH
FORSCHUNGSZENTRUM

Characterization of BPM pickup designs for the HESR @ FAIR using simulations and numerical calculations

Arbeitskreis Beschleunigerphysik 12.2:
Beam Diagnostics

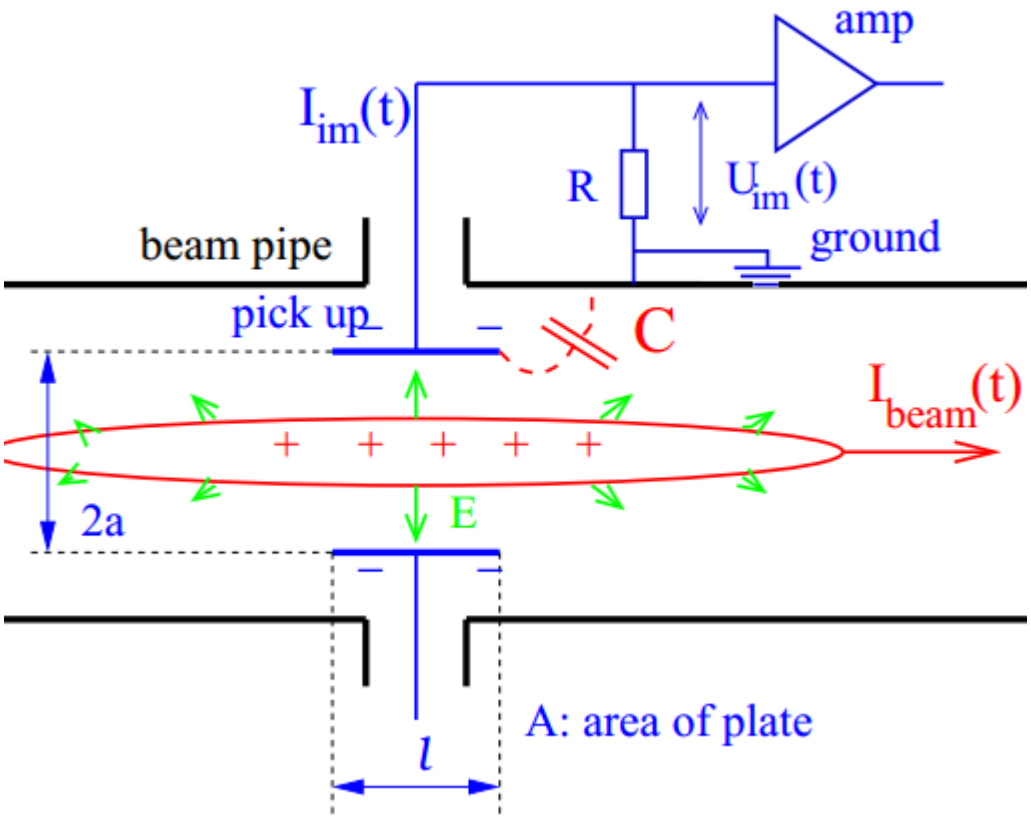


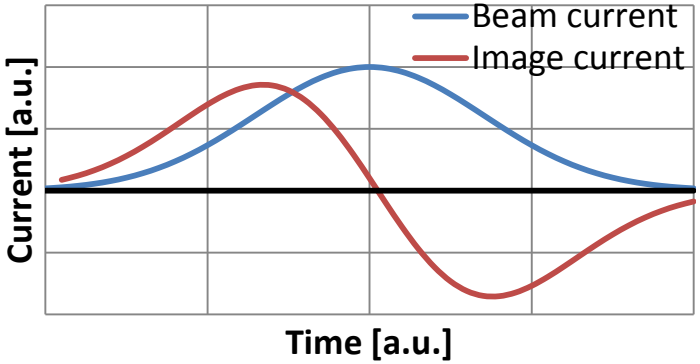
IKP-4, Forschungszentrum Jülich
A.Halama, March 17, 2016 | 14:15

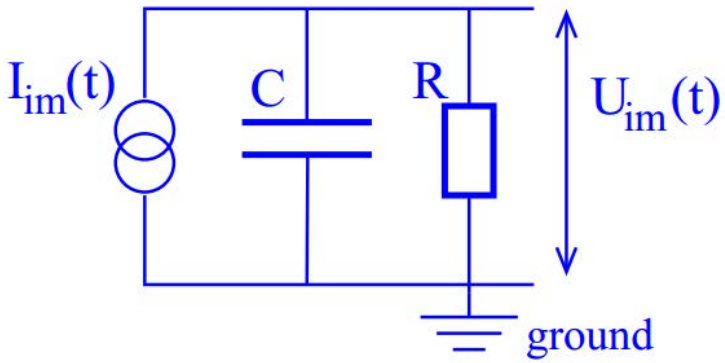
Contents

- Quick capacitive BPM basics
- A look at both designs
- Position dependent properties
  - Signal yield
  - Sensitivity
- Unwanted inherent features / characteristics

Image current flowing onto and from the electrodes → differenciated signal shape



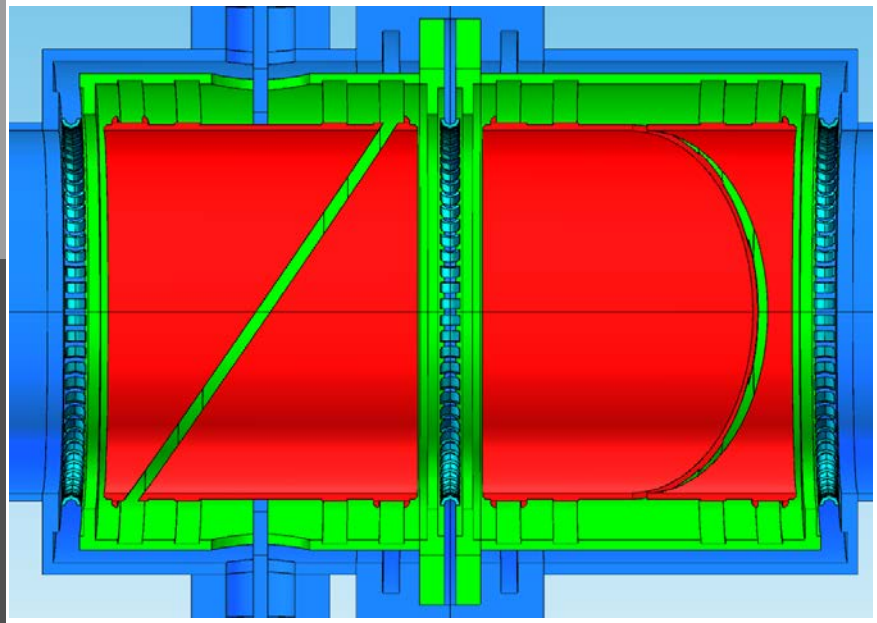


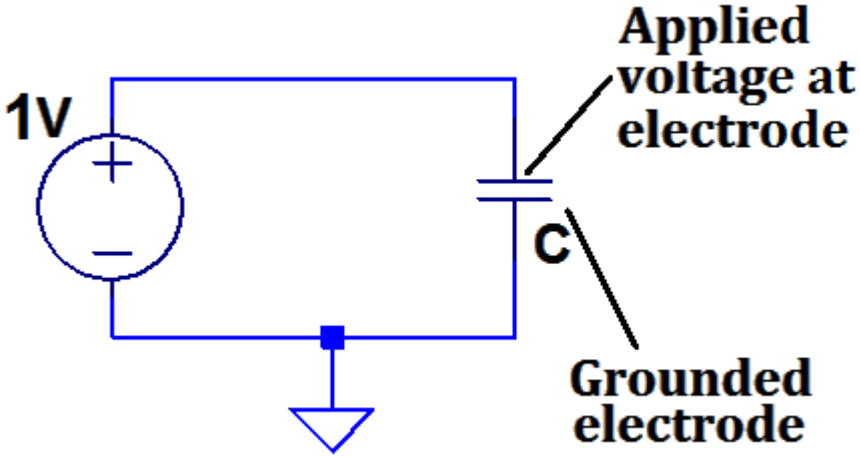


$$I_{im}(t) = -\frac{N\ e\ t\ L_{BPM}}{2\sqrt{2\pi}\ \sigma^3 \beta\ c}\ e^{-\frac{1}{2}(\frac{t}{\sigma})^2}$$

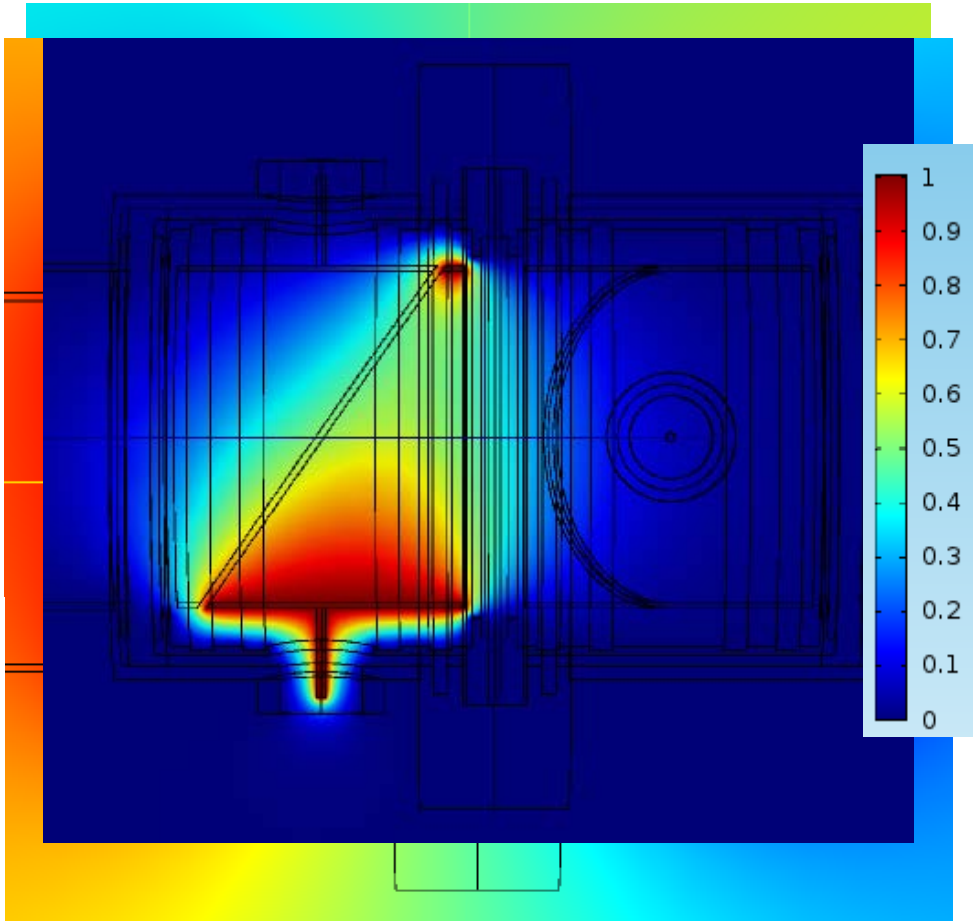
Sources: „Beam Position Monitors“ by P. Forck, P. Kowina, D. Liakin, GSI

Capacitance determination using COMSOL



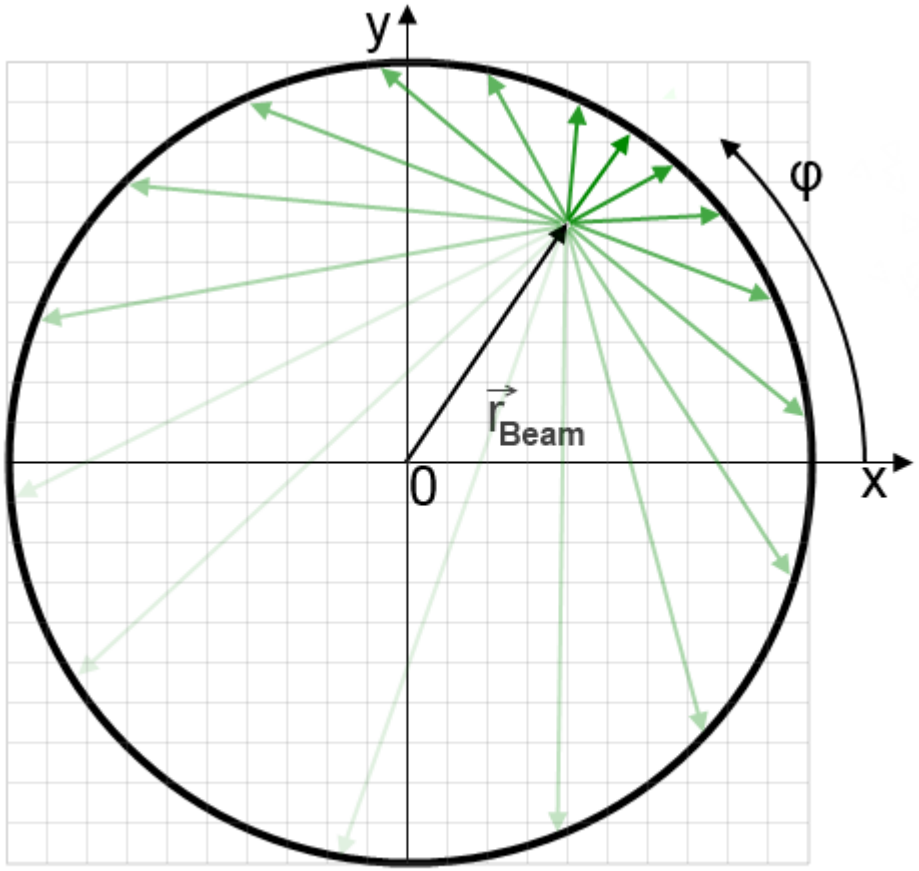


Electrical potential, [V]



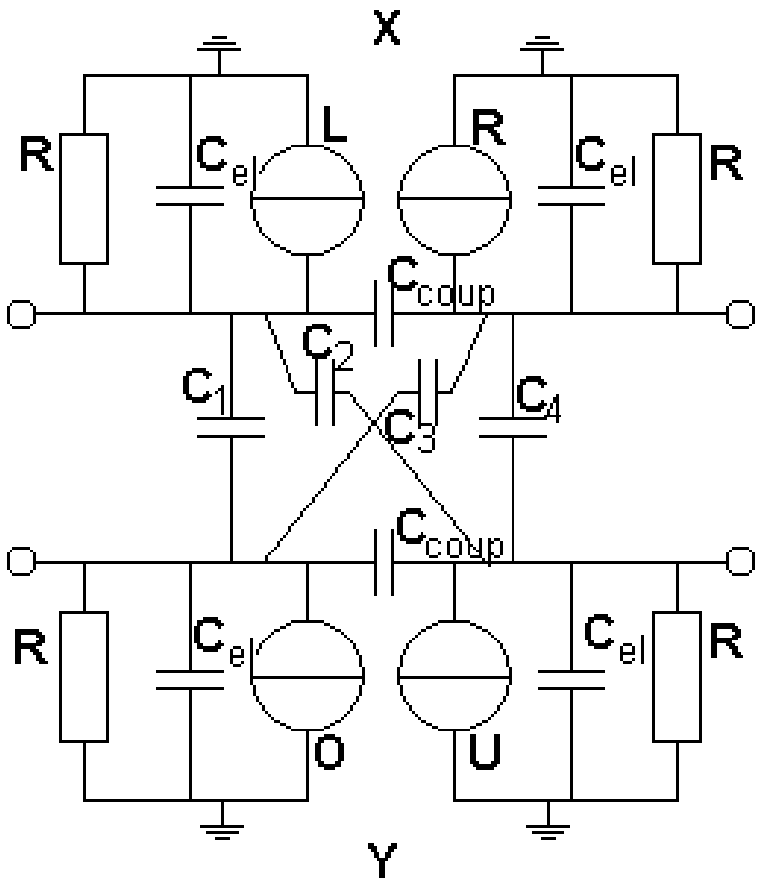
Electric field simulation leads to capacitances as a byproduct

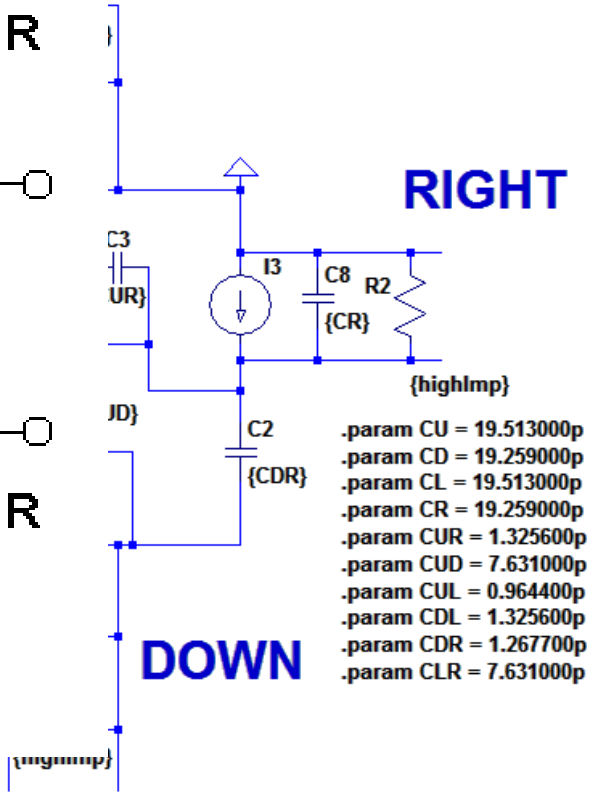
Image current scaling factors given by position dependent influence



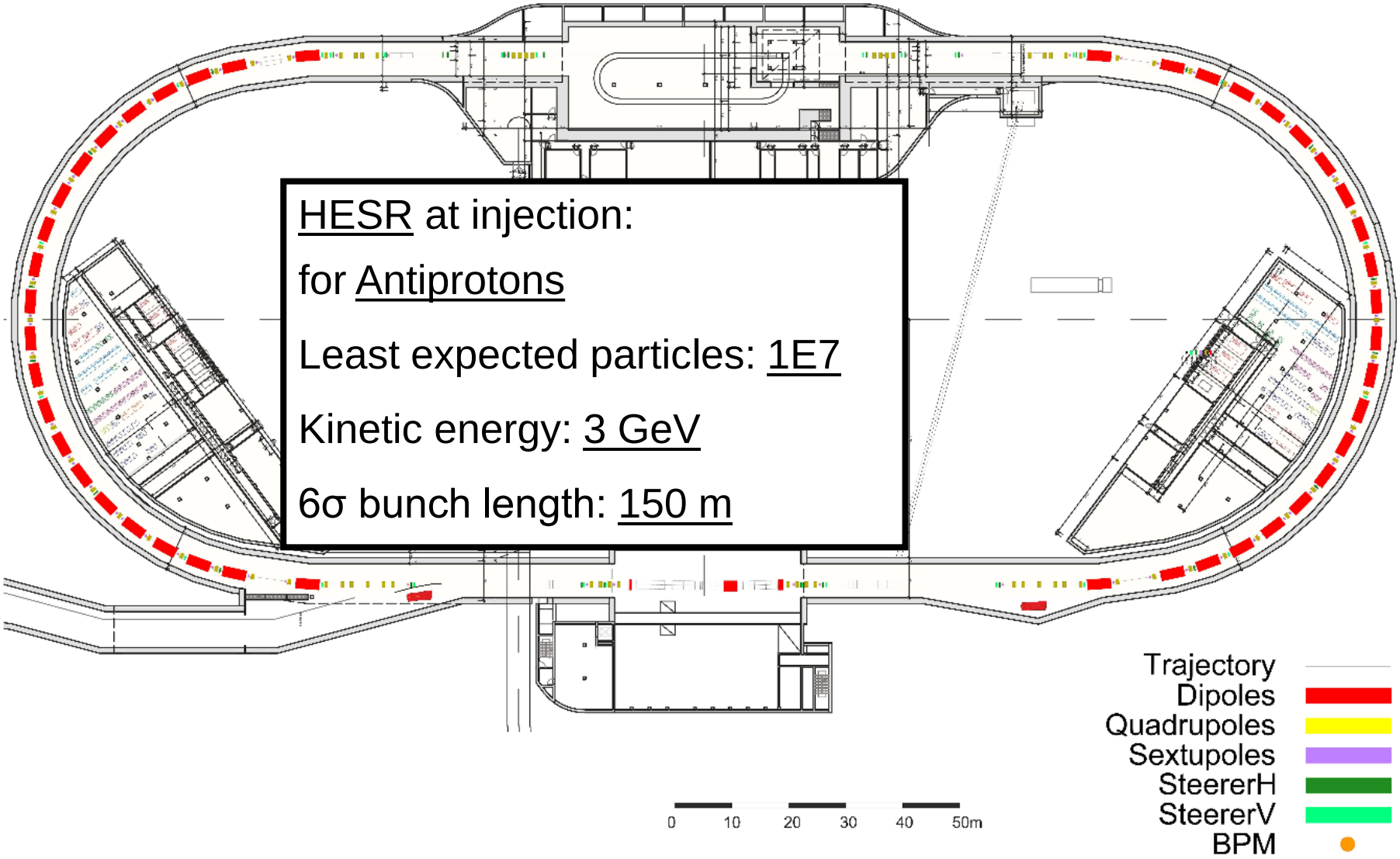
$$Influence \propto \int_{\varphi_0}^{\varphi_1} \frac{l(\varphi)}{(\cos(\varphi)\, r_{BPM} - X_{beam})^2 + (\sin(\varphi) r_{BPM} - Y_{beam})^2} d\varphi$$

Equivalent circuit for 4 electrodes





Considered Input Parameters



Sources: IKP database / http://www.fz- juelich.de/ikp/DE/Forschung/Beschleuniger/HESRfuerEinsteiger_node.html

Both BPM Designs

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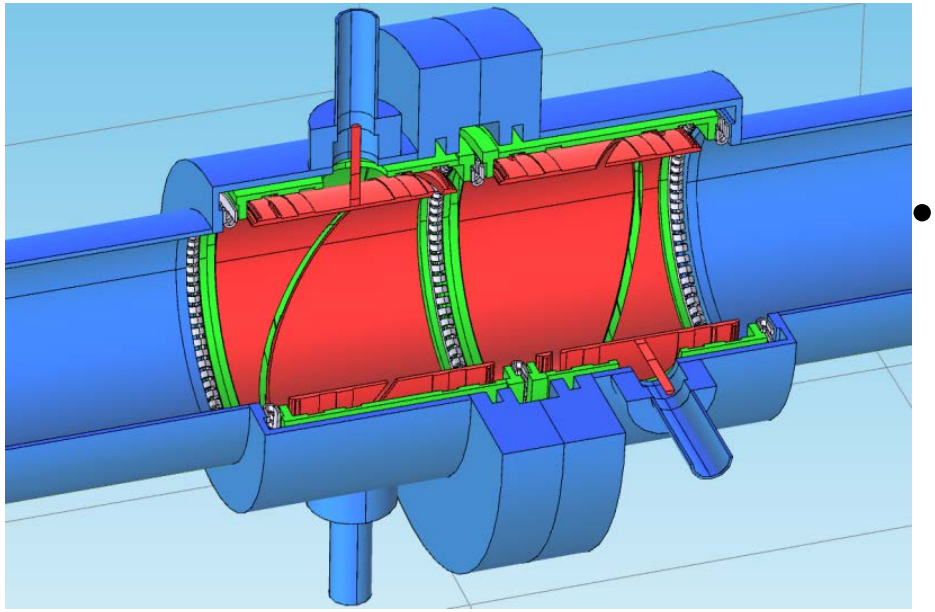
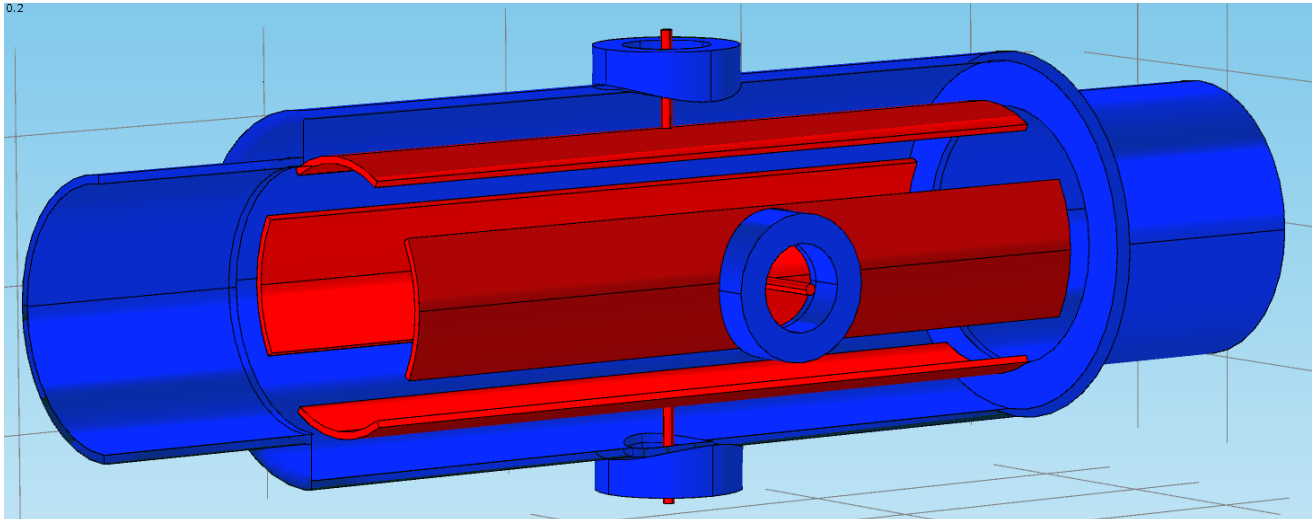
Cylindrical diagonally cut

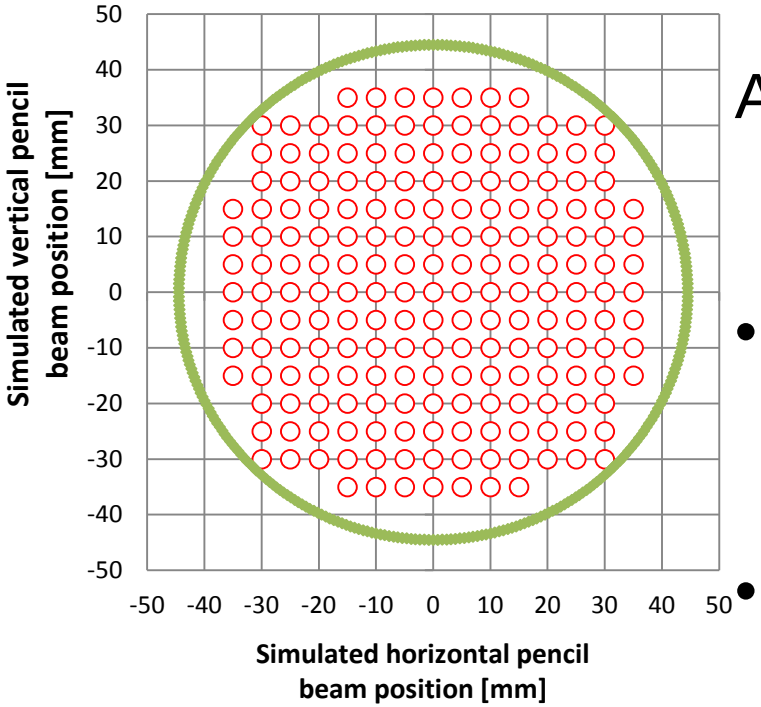


- Antiproton turn-by-turn measurement at injection is unlikely with current design.
- Higher signal level, S/N-ratio and sensitivity expected with less coupling expected.

Symmetric quad strips



Simulating each beam position



○ actual beam position

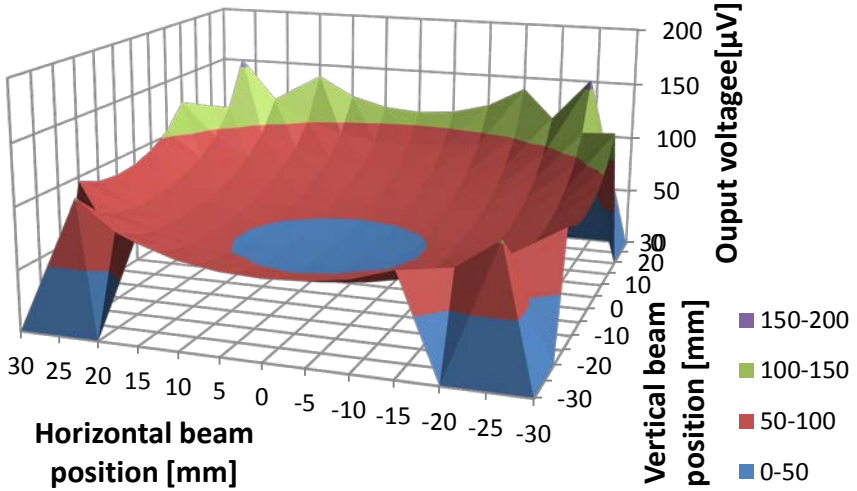
◆ Electrodes

After capacitance determination;

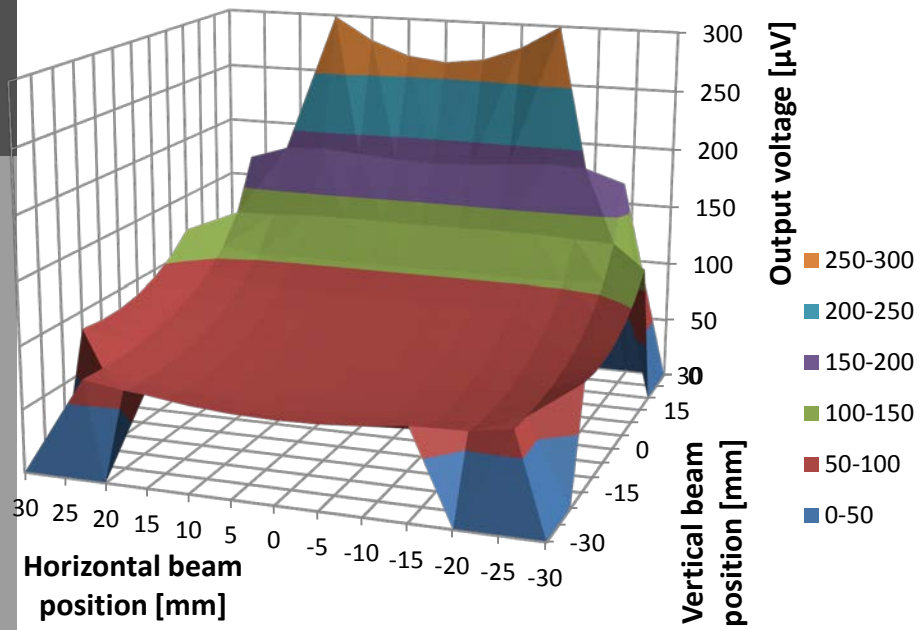
- Retreive scaling factors for each beam position for all electrodes
- Run through equivalent curcuit
- Analyse output voltages

Signal level distributions

Cylindrical diagonally cut



Symmetric quad strips



Peak output voltage distribution at a single electrode at high impedance, R

Peak output voltages at center:

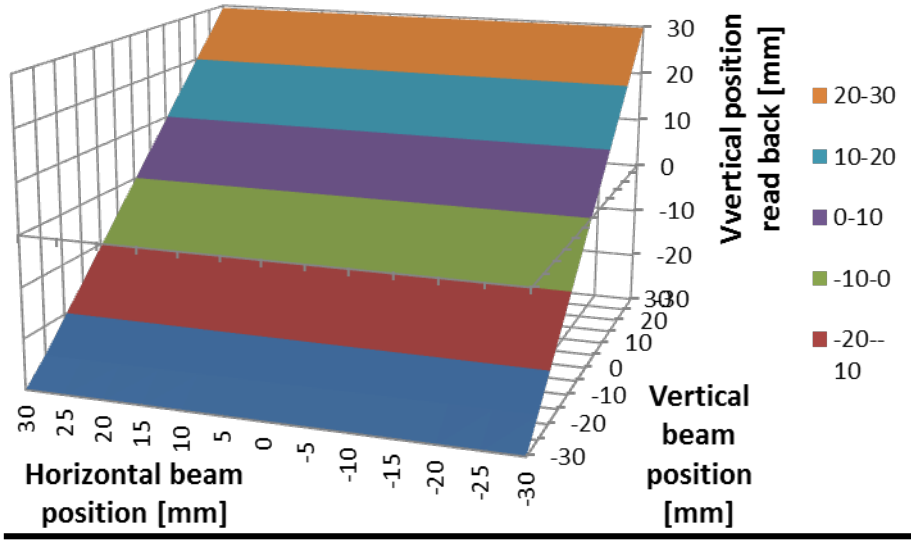
Cyl. diag cut: ~48µV

Symm. quad: ~63µV

Strip BPM distribution is steeper and suggests higher sensitivity

Position determination

Cylindrical diagonally cut

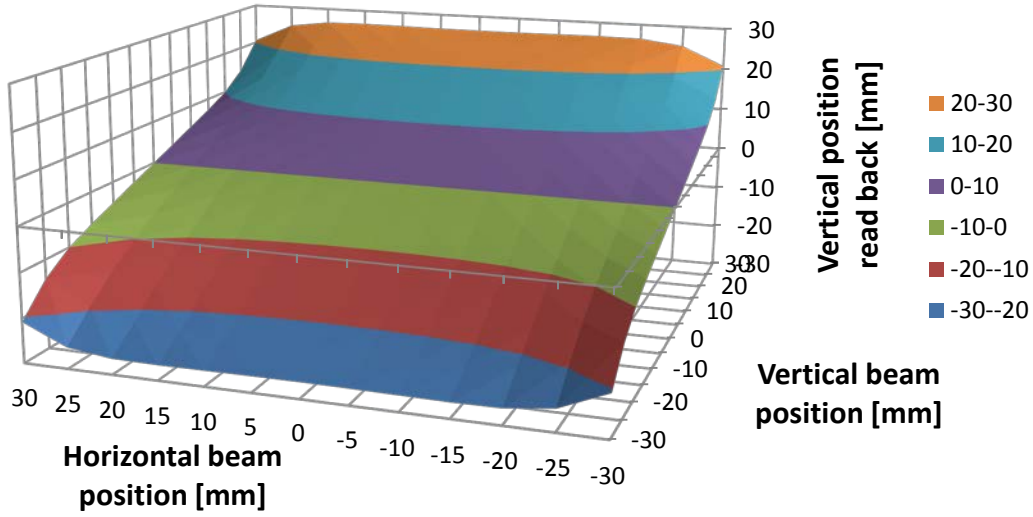


$$S_y(x,y) = \frac{\mathrm{d}}{dy}\frac{\Delta_y(x,y)}{\Sigma_y(x,y)} = \frac{d}{dy}\frac{U_U - U_D}{U_U + U_D}$$

$$y = \frac{1}{S_y}\frac{\Delta_y}{\Sigma_y} \qquad x = \frac{1}{S_x}\frac{\Delta_x}{\Sigma_x}$$

Average sensitivity:
S_y = 0.84 %/mm

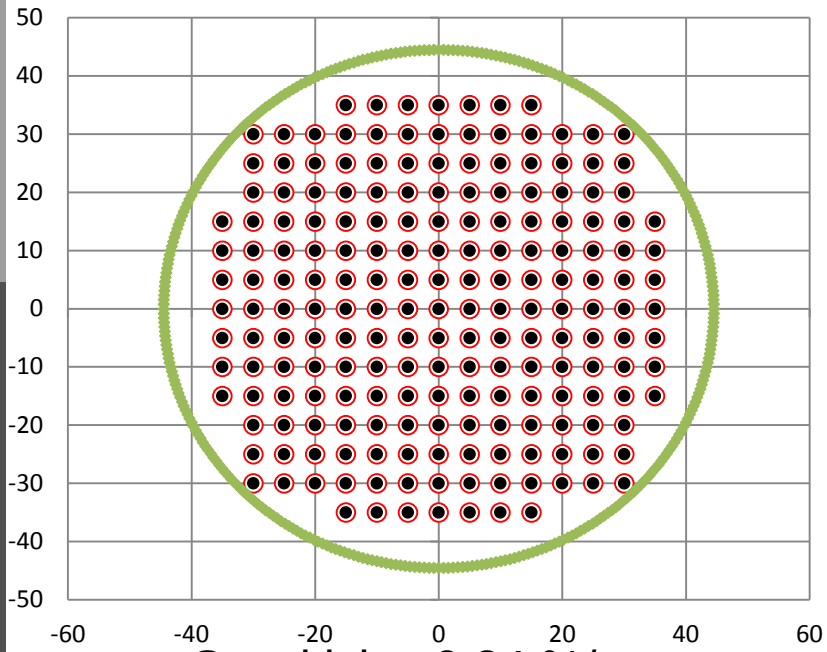
Symmetric quad strips



Center sensitivity:
S_y = 2.28 %/mm

Position projection

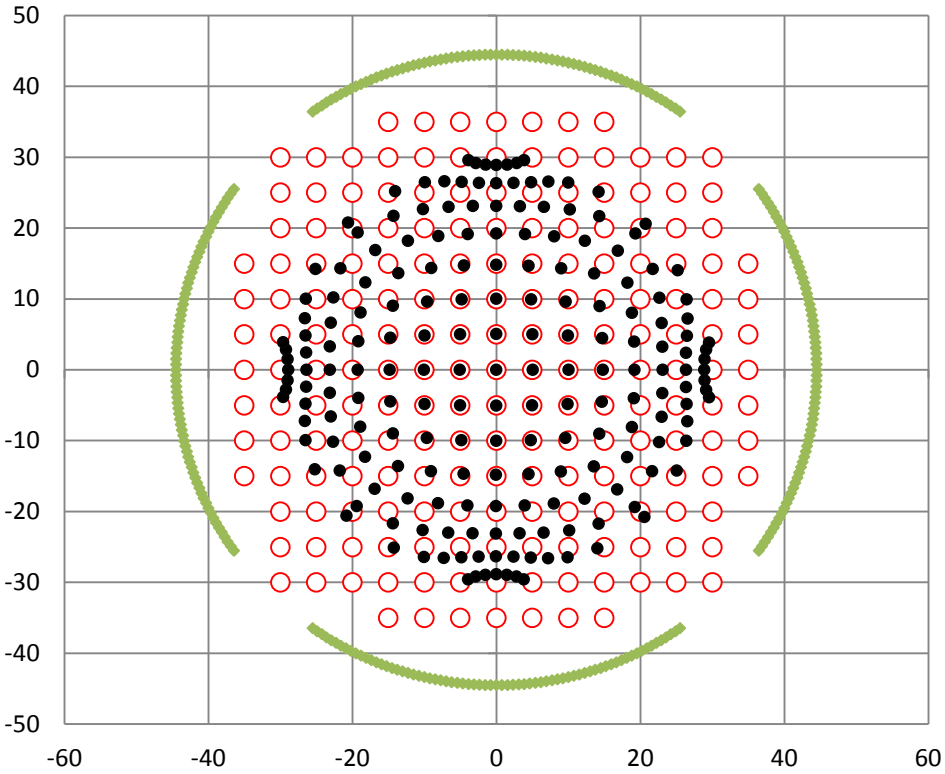
Cylindrical diagonally cut



Sensitivity: 0.84 %/mm

$$y = \frac{1}{S_y}\frac{\Delta_y}{\Sigma_y}$$

Symmetric quad strips

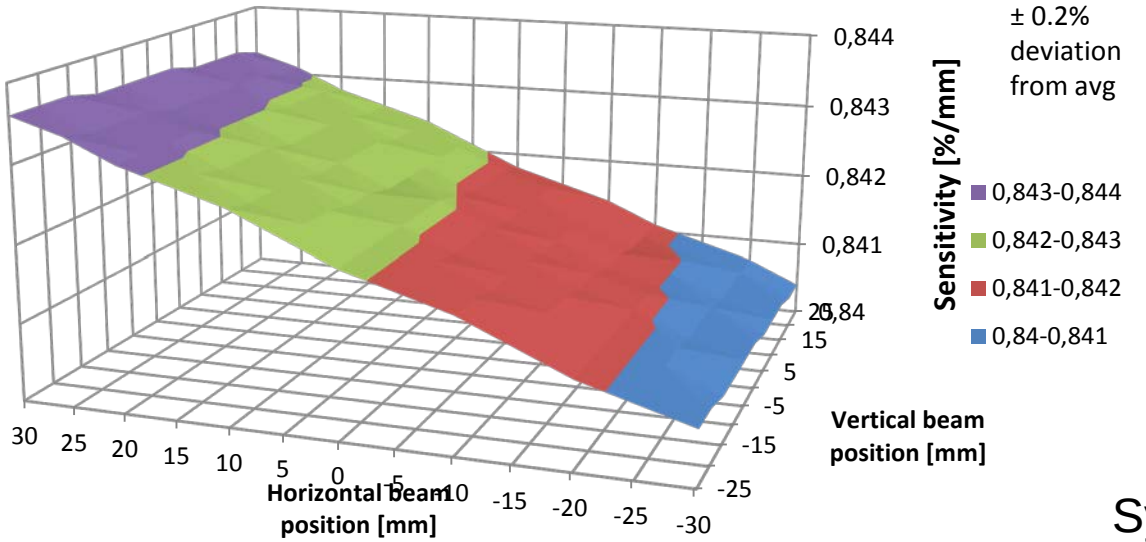


Sensitivity: 2.28 %/mm

- ○ actual beam position
- ● projected beam position
- ◆ Electrodes

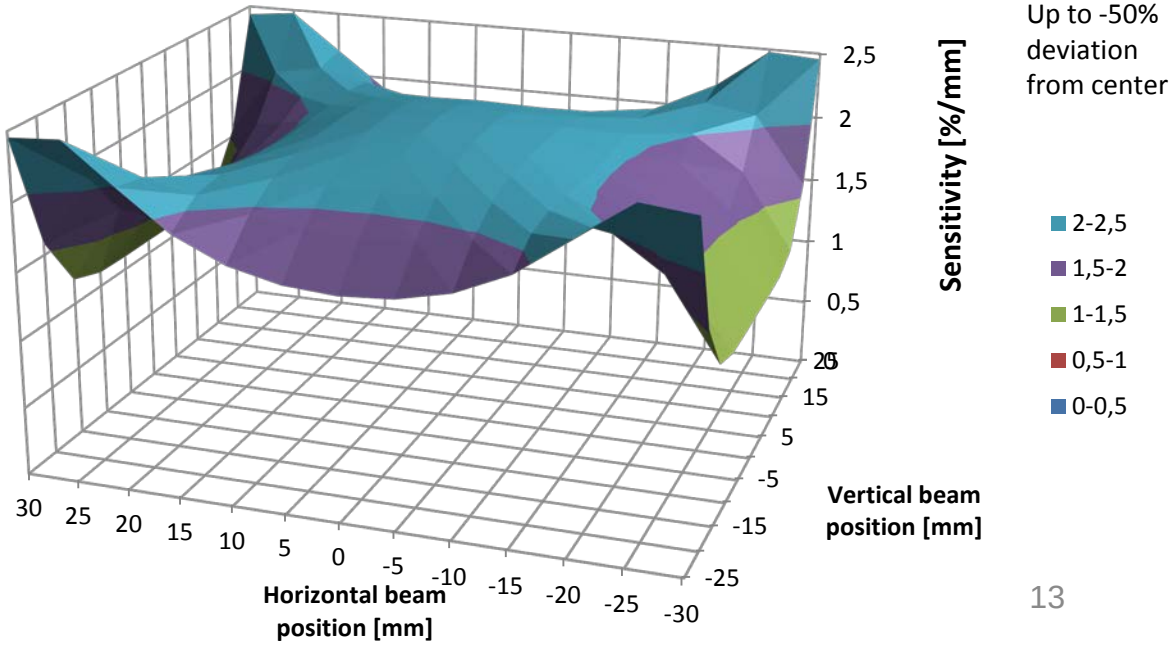
Sensitivity distribution

Cylindrical diagonally cut



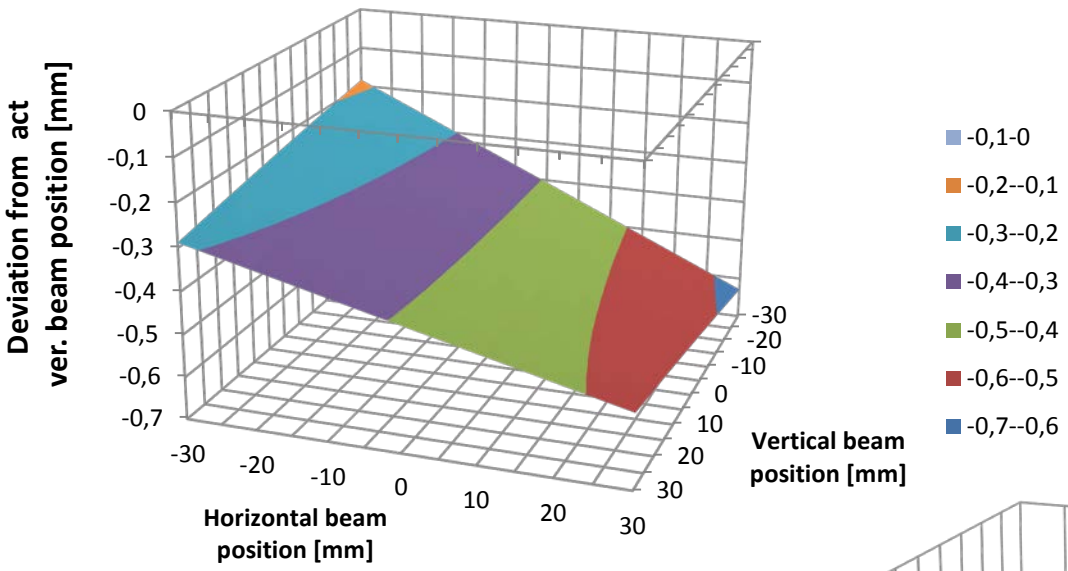
$$S_y(x,y) = \frac{d}{dx}\frac{\Delta_y(x,y)}{\Sigma_y(x,y)}$$

Symmetric quad strips



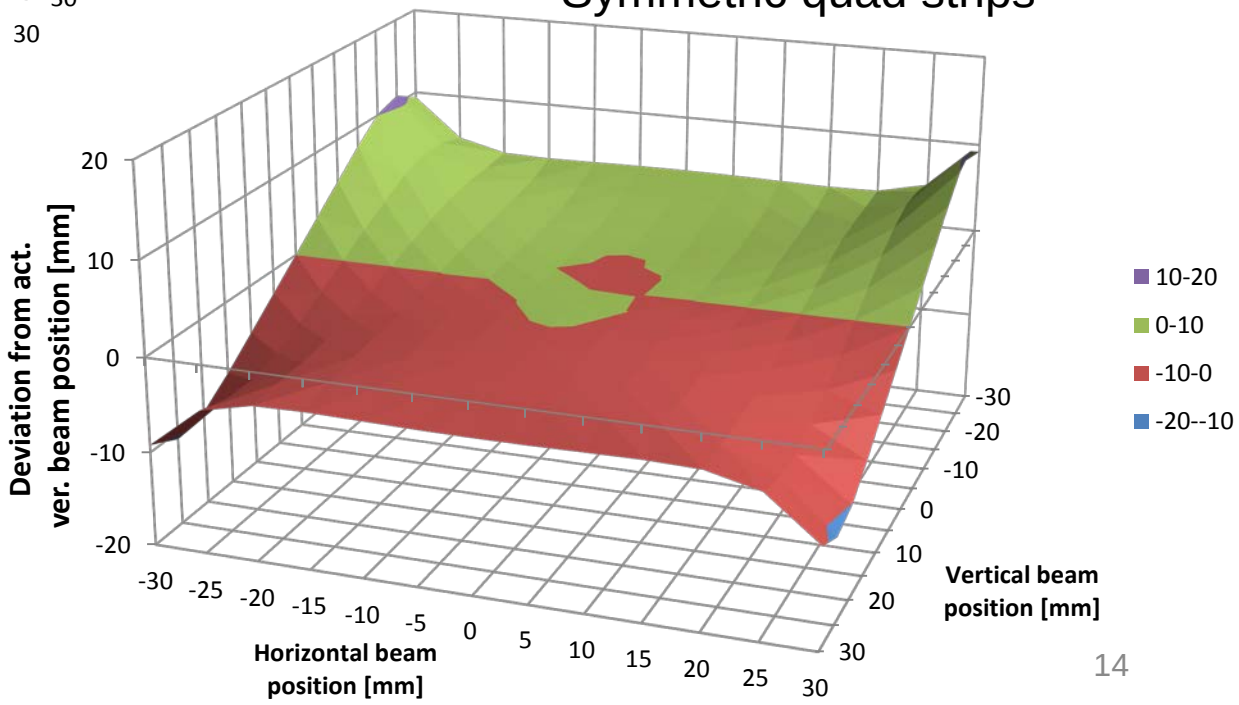
Unwanted inherent features

Cylindrical diagonally cut



- Offset
- Asymmetric coupling

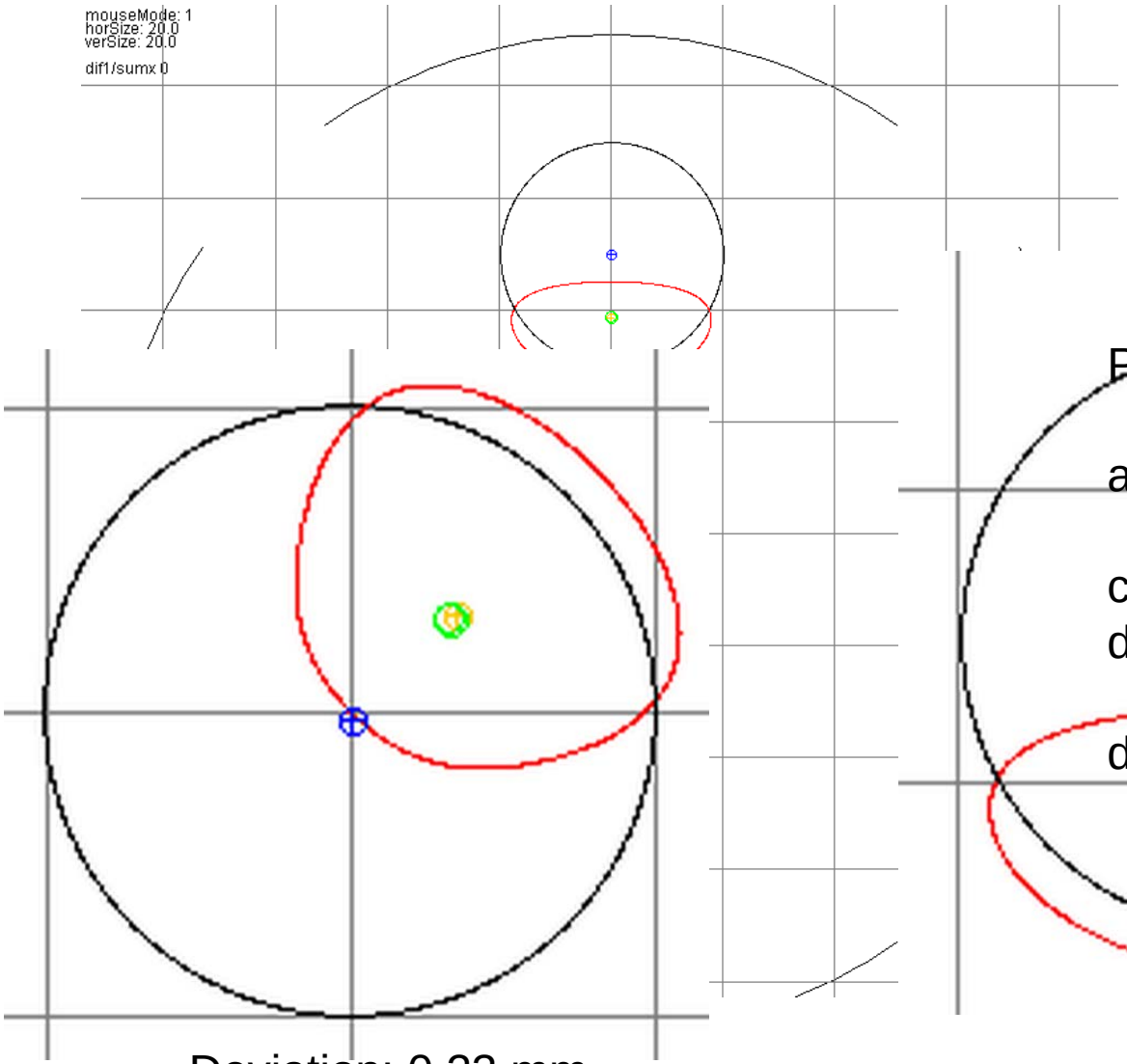
Symmetric quad strips



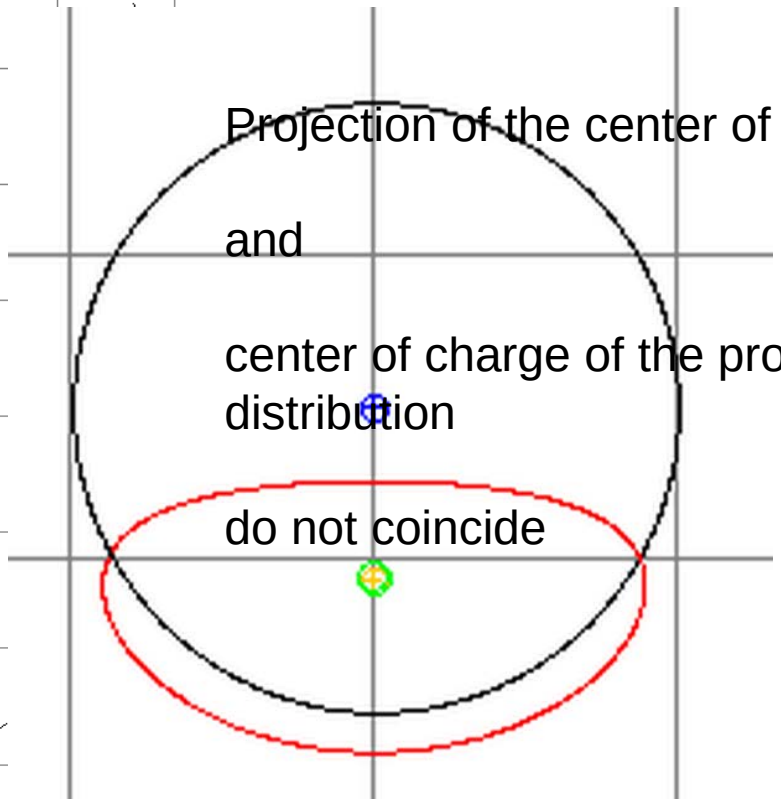
Inherent unwanted features

Symmetric quad strips

- Offset
- Asymmetric coupling
- False projection of charge distribution



Deviation: 0.23 mm



Projection of the center of charge

and

center of charge of the projected distribution

do not coincide

0.1mm

Thank you

References

- C. Böhme - Annual Report 2014: „Beam Position Monitors for the HESR “ & AR2015: „Status of the HESR BPM “, FZJ
- P. Forck, P. Kowina, D. Liakin: „Beam Position Monitors“, GSI
- R.E. Shafer: „Beam Position Monitoring“

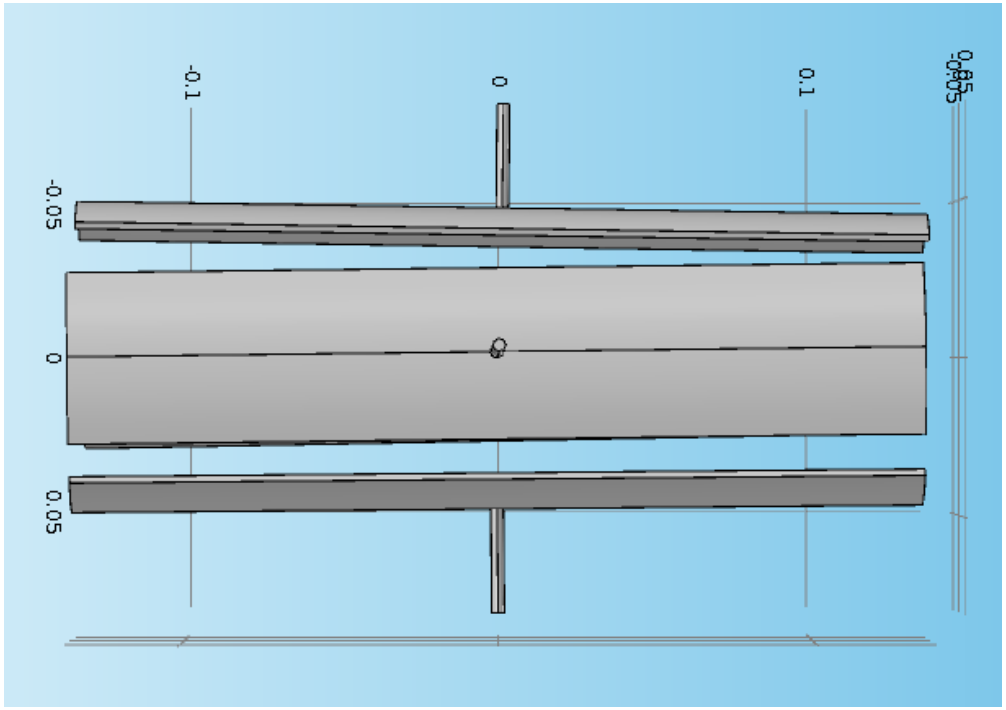
Tolerance induced errors

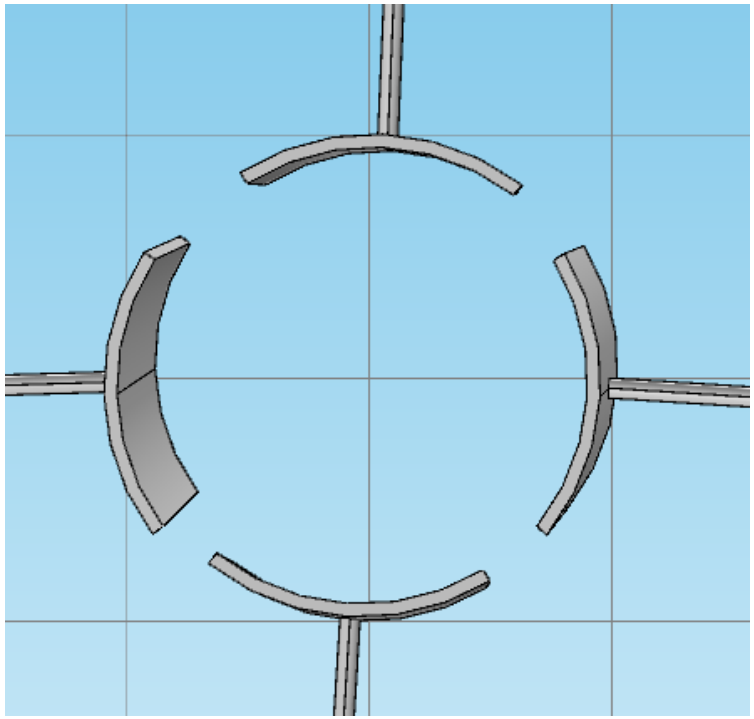
Randomly skewed electrodes were

yaw: 1.45° ~= 25 mrad; pitch: 1.45° ~= 25 mrad; roll: 4.00° ~= 70 mrad

each 1-dim. offset : 2 mm

At least 20% of this error +80 % random





Tolerance induced errors

$\alpha_{rms} = 0.95°$; $\beta_{rms} = 0.94°$; $\gamma_{rms} = 2.6°$; $x,y,z_{rms} = 1.28$ mm

$(\Delta C / C)_{rms} = 1.27\ \%$ (Capacitances)

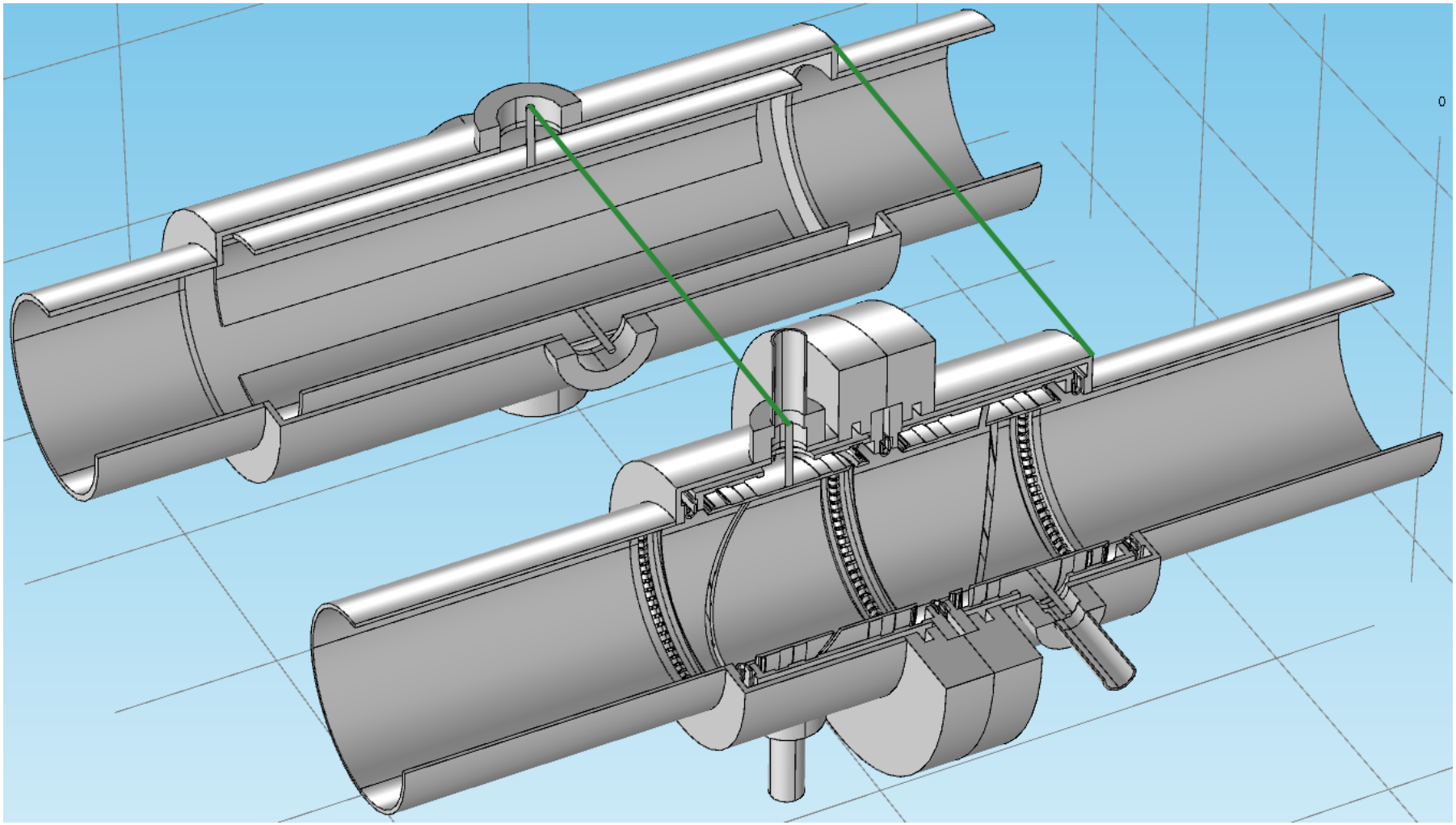
$(\Delta F_{curr}/F_{curr})_{rms} = 1.15\%$ (Scaling factors)

$(\Delta X / X)_{rms} = 34{,}7\ \%$ (Beam Position)

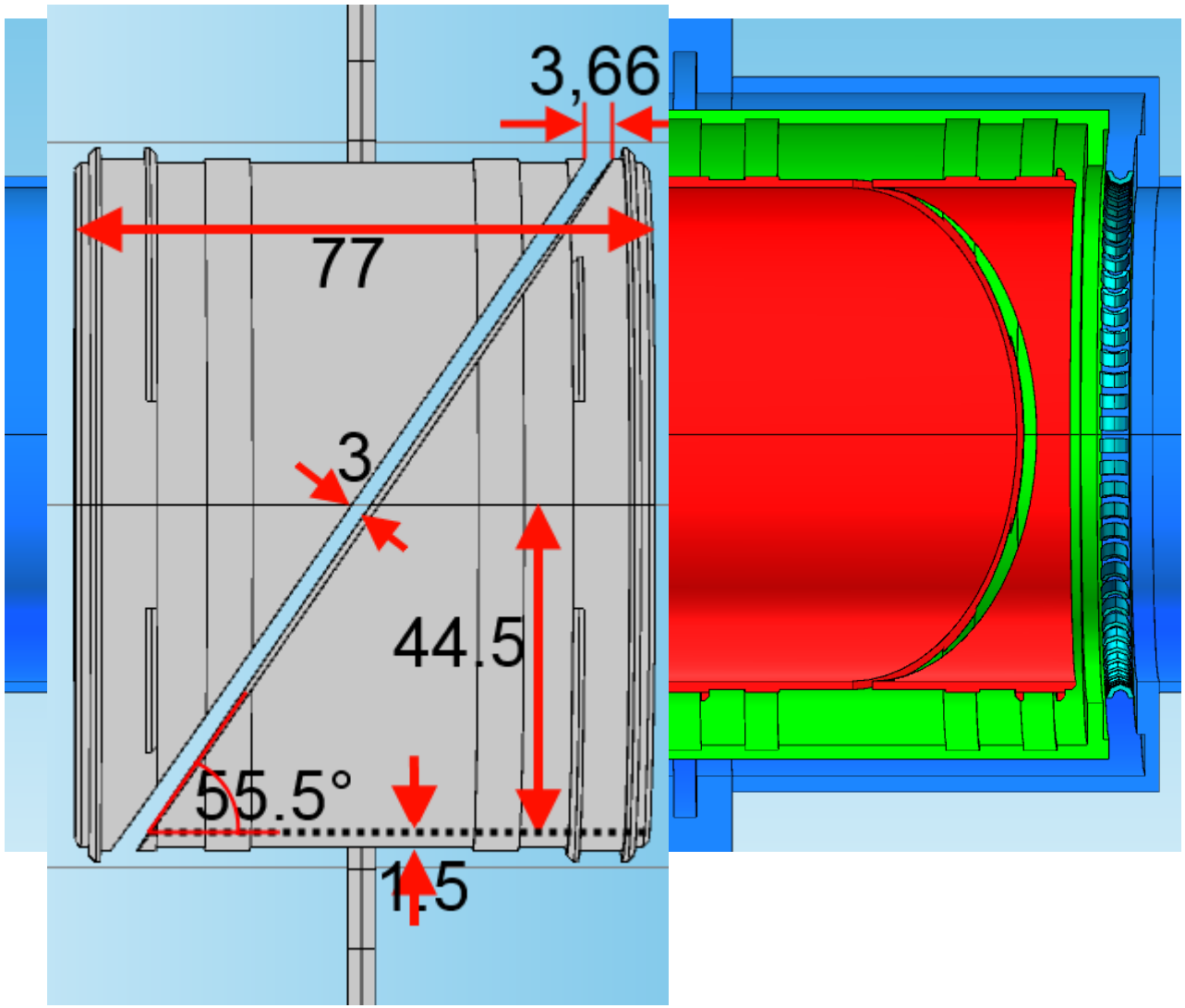
$(\Delta S_x / S_x)_{rms} = 13{,}8\ \%$ (Sensitivity)

$X_{offset\ rms} \approx 2$ mm (Electrical Offset)

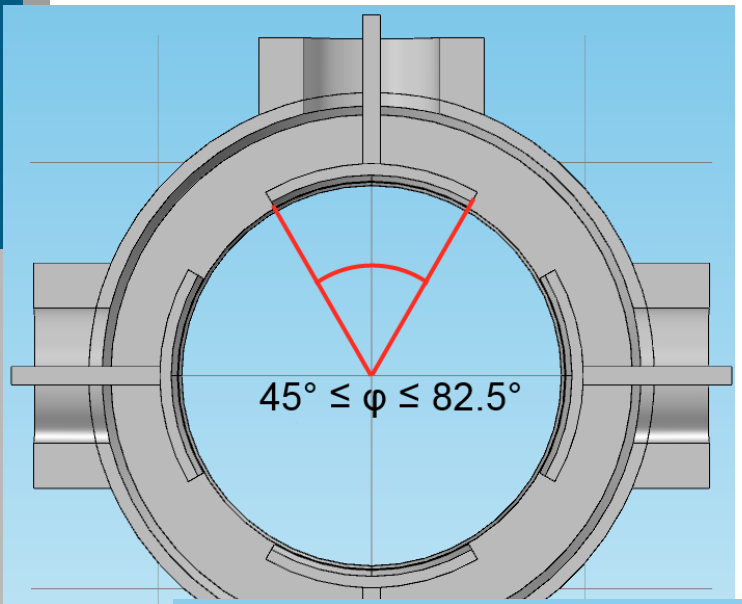
Considering Length of Electrode



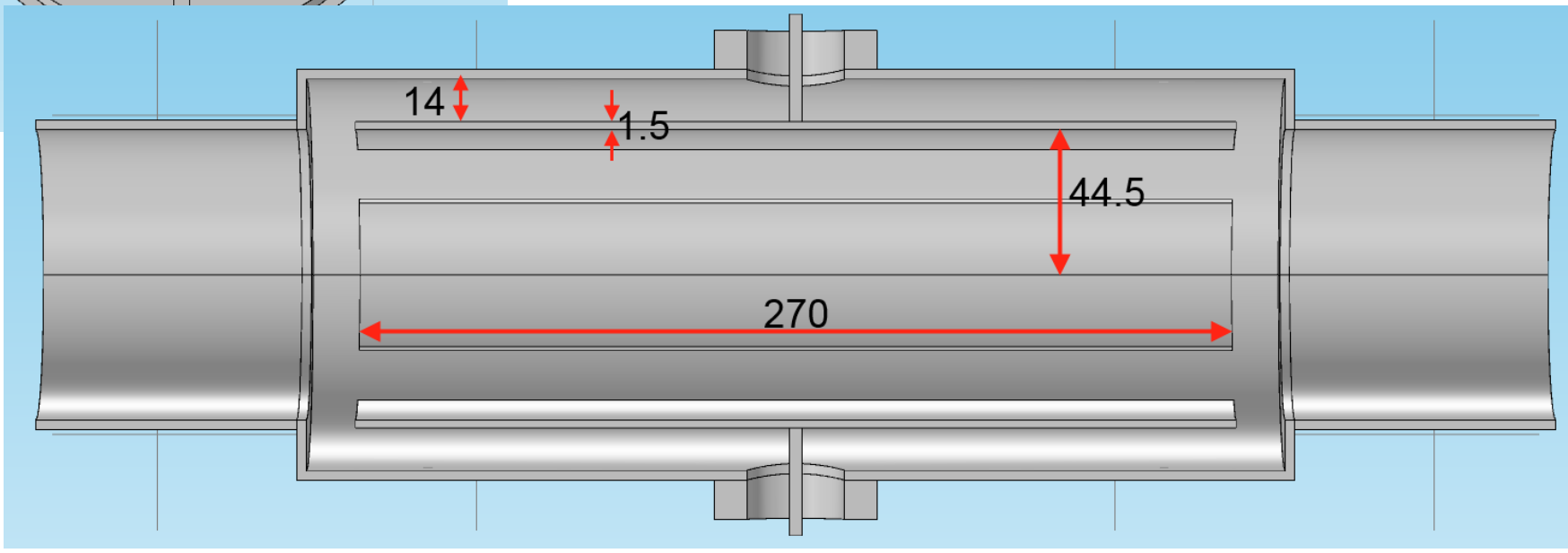
Cylindrical Diagonal Cut BPM PU



New BPM PU Design Concept

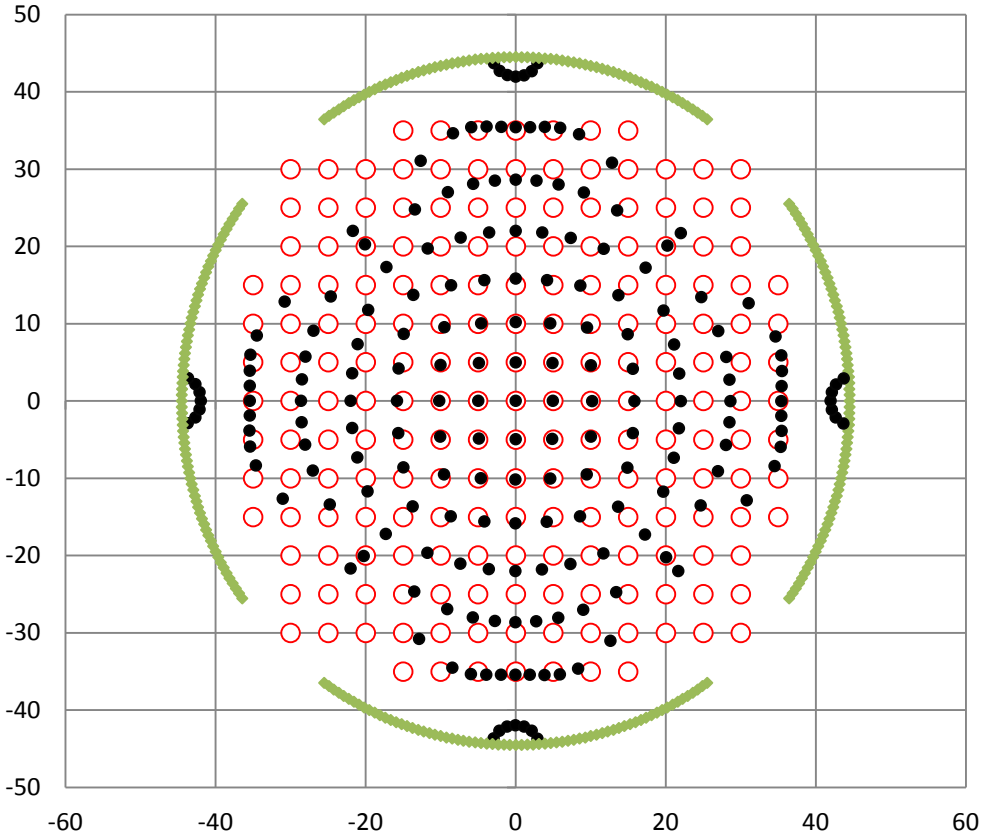


Greatest length of PU (270 mm) while being symmetric



More position determination formulae

$$\ln\left(\frac{U1+U2}{U3+U4}\right) \rightarrow 3.32\ \%/\mathrm{mm}$$



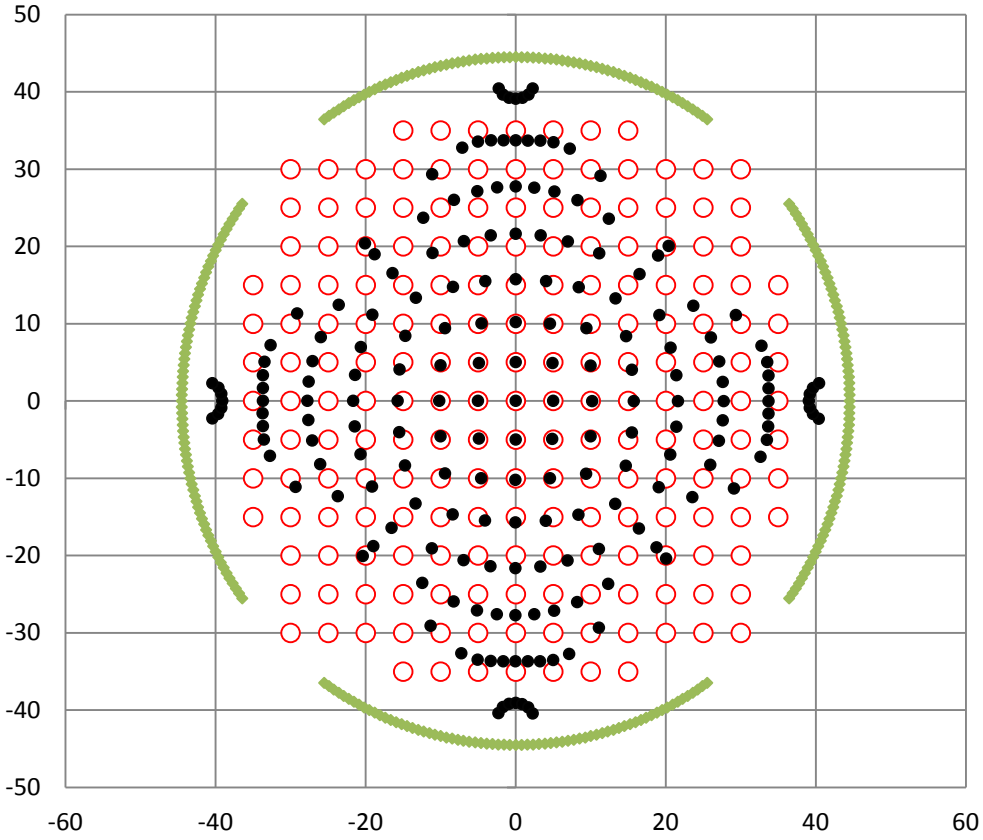
○ actual beam position

● projected beam position

◆ Electrodes

More position determination formulae

$$\frac{\Delta_y}{\Sigma_{xy}} \rightarrow 1{,}17\ \%/\mathrm{mm}$$



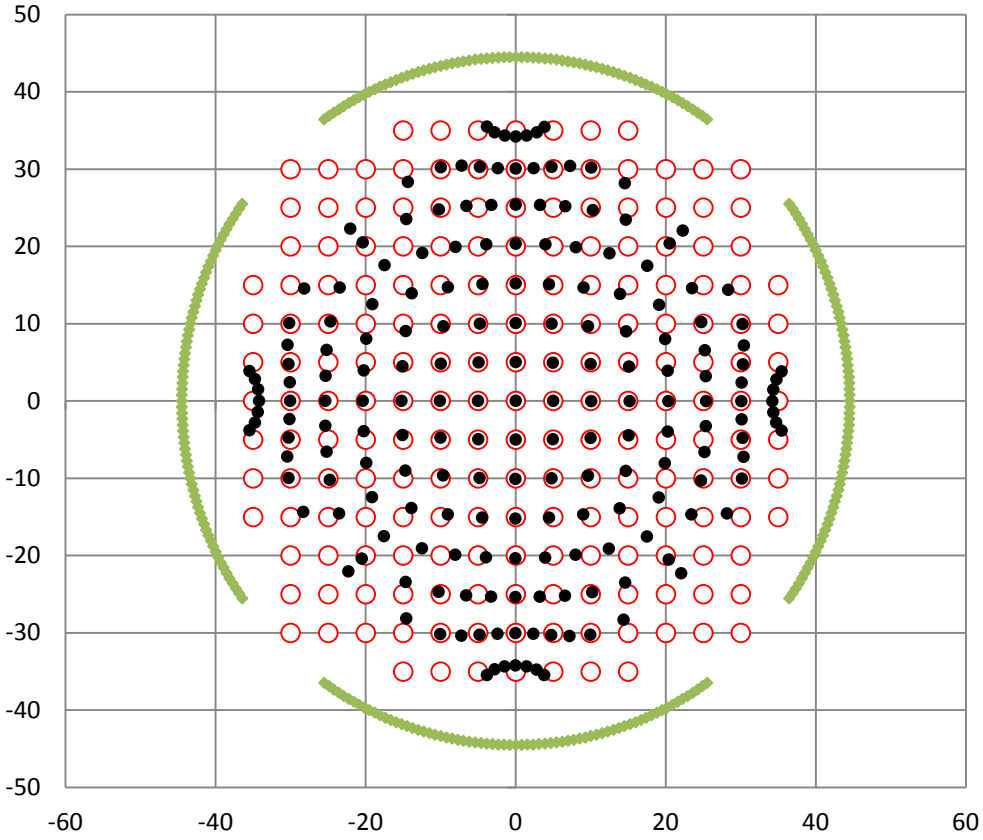
○ actual beam position

● projected beam position

◆ Electrodes

More position determination formulae

$$\ln\left(\frac{Up}{Down}\right) \rightarrow 4.63\ \%/\mathrm{mm}$$



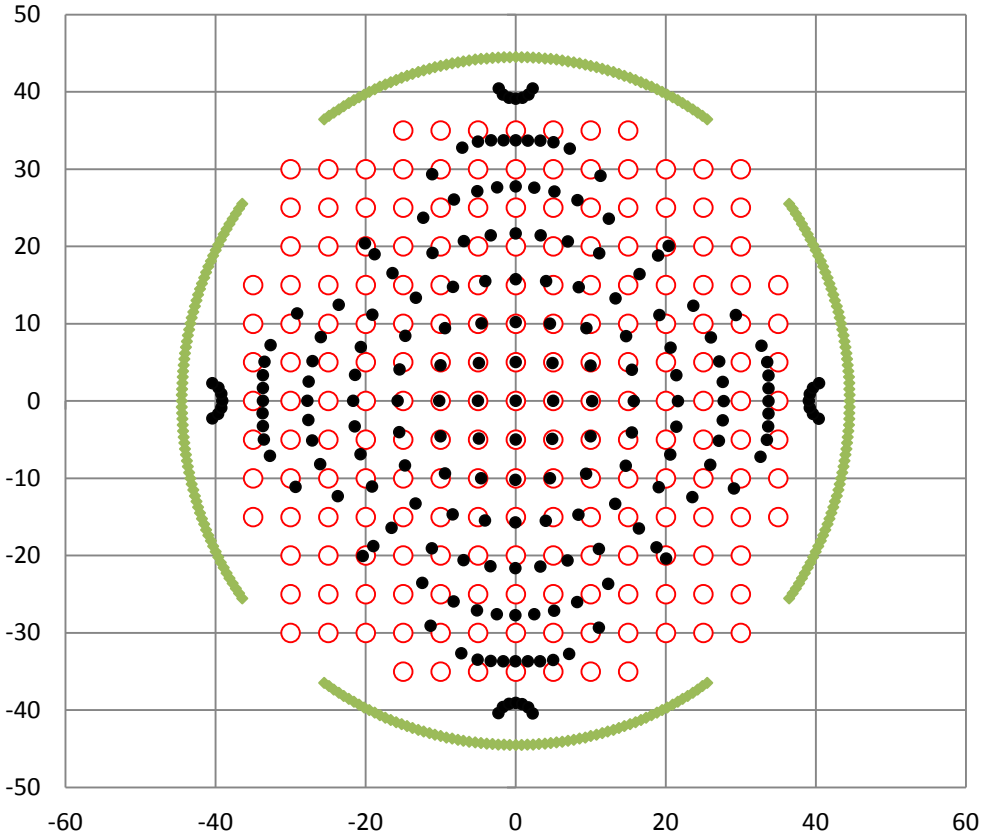
○ actual beam position

● projected beam position

◆ Electrodes

More position determination formulae

$$\frac{U1+U2-U3-U4}{\Sigma_{xy}} \rightarrow 1{,}65\ \%/\mathrm{mm}$$



○ actual beam position

● projected beam position

◆ Electrodes